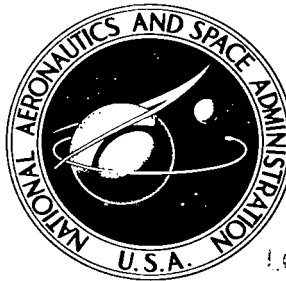


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# CONVERSION OF A SPACECRAFT DESIGNED FOR MANNED SPACE FLIGHT TO A RECOVERABLE ORBITING ASTRONOMICAL OBSERVATORY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

A preliminary study has been made of the conversion of a spacecraft designed for manned space flight, for example, the Mercury spacecraft, to a recoverable orbiting astronomical observatory. The recoverable observatory can be instrumented to perform a wide range of astronomical observations. The optical equipment used for this study consists of 76-centimeter cassegrainian telescope with two secondary mirrors, one for narrow-field and one for wide-field observations. The particular conversion of a spacecraft discussed in this paper is for high-resolution photography and photometric studies of discrete objects and of the interstellar and intergalactic background. Data would be recorded by six cameras that would cover the electromagnetic spectrum from 1,220 Å to 11,000 Å. The results, which are preliminary in nature, indicate that the conversion is feasible and that a worthwhile contribution could be made to astronomy. An information gain up to a factor of 10 over telemeter data recovery systems may be obtained provided the fine control system can hold drift to less than the 0.08 second of arc during any exposure.

INTRODUCTION

The elimination of the earth's atmosphere as an impediment to observation has long been the desire of the astronomer. Such an achievement would eliminate (1) the selective absorption of the earth's atmosphere, (2) the scintillation of the earth's atmosphere as a factor in astronomical seeing and thus increase the effective resolution of telescopes, and (3) the night-sky brightness caused by photochemical processes in the earth's atmosphere and manmade light sources.

The development of the capability of launching large earth satellites makes possible an orbiting astronomical observatory. If the orbit is at least 500 kilometers above the earth's surface, the noted atmosphere effects will be eliminated as impediments to observation. In addition, the data from the recoverable observatory could be used to establish a reference point for the calibration of observations made with earthbound telescopes.

Current plans for space astronomy are concentrated on a nonrecoverable satellite called the Orbiting Astronomical Observatory (OAO). Because this vehicle is nonrecoverable, the data that its instruments obtain must be telemetered back to earth. Insofar as can be determined the U.S. National Space Program does not, at present, include plans for an unmanned recoverable orbiting astronomical observatory or for a recoverable data package that would permit the original data to be recovered.

The man-in-space program has developed a series of recoverable spacecrafts for manned space flight. This paper presents the results of a preliminary study of the conversion of one of these spacecrafts, the Mercury spacecraft, to a recoverable orbiting astronomical observatory. On the basis of this study it appears that the conversion is feasible and up to 10 times as much information would be obtained from the recoverable observation system as would be obtained from telemeter data recovery from a similar observation system mounted in a non-recoverable vehicle. In order to obtain the noted information gain the drift of the recoverable vehicle and observing system must be less than 0.08 second of arc during the time a camera is recording an image. The conversion considered in this paper is one for high-resolution photography and would have a band pass from 1,200 Å to 11,000 Å.

The author wishes to thank Dr. G. C. McVittie, of the University of Illinois, and Dr. L. W. Frederick, of the University of Virginia, for their helpful discussions concerning observations and the image tubes used in the observing system.

#### GENERAL CONSIDERATIONS

Current space astronomy plans for the observation of stars, nebulae, and galaxies from satellites in orbit about the earth are based on the use of the Orbiting Astronomical Observatory currently under development by the NASA Goddard Space Flight Center. This observatory is a nonrecoverable vehicle in which the data are telemetered back to earth. There are no immediate plans for recovering the original data records from this observatory.

The man-in-space program has provided the astronomical community with the latent ability to recover observational data. The spacecraft used in the Mercury and other manned space flight programs are recoverable, and if these could be adapted to astronomical observation, the recovery capability would permit the recovery of exposed and developed photographic film of astronomical objects.

Photographic film is one of the best information storage devices yet devised and its information content is probably the highest. As a recorder, film, unlike other devices, for instance photomultipliers, records the position and the event at the same time on the same piece of material. Film records all events that are intense enough to register in the field being surveyed. This statement means that in addition to the event for which the exposure was made, other events are recorded. This additional information can be considered latent in that they are not of interest to the observer. This latent information capacity has often been used in astronomy to supply additional information on an object after

discovery. (See refs. 1 to 3 for examples of the use of film libraries in this way.) In addition, the recording ability leads to accidental discovery of phenomena.

Television and photomultiplier methods are inferior to film from an information point of view. (See refs. 4 and 5.) As pointed out in reference 5 (pp. 104-114), film in spectroscopic applications contains at least 10 times as much information as a photomultiplier recording of the spectrum. This information advantage should carry over to photography if the fine stabilization system is sufficiently accurate.

There are two types of photographic systems that are competitive for use in space astronomy; in one the processed film is recovered and in the second the processed film is read and data transmitted by telemeter and the picture reassembled from the transmitted data. In order to compare these two systems, it is assumed that identical telescopes record on the same film and both telescopes are stabilized in the same way to the same accuracy. The film has a resolution of 60 line pairs per millimeter for high contrast objects when properly developed. It is assumed that both films are developed in the same way.

At the end of the development process each film has the same resolution, 60 line pairs per millimeter, and this value is also the resolution of the recovered film. In the case of telemetered data the photograph must be read by a film readout system and the data transmitted by telemeter to a ground station and reassembled into a picture. It appears that, at the time of writing, a film readout system can quantize a picture to the equivalent of 60 line pairs per millimeter in the vertical and horizontal directions. The reading process produces a loss of information and the information content of the stored quantized picture is less than the original. Information losses also occur through all of the other processes in the data-recovery sequence. Preliminary calculations indicate that the information content of the reassembled picture will be the equivalent of film having a resolution of 45 line pairs per millimeter. This result indicates that recovering the film returns about twice as much information as reading film and returning the data by telemeter methods. In order to take full advantage of recovery of film, the smear produced by stabilization must be significantly less than the line pair width of the reconstructed picture. The width of a line pair in the reconstructed picture is about 0.02 millimeter; thus, smear should be, at most, 50 percent of that width or about 0.01 millimeter. This result means that the drift must be less than 0.08 second of arc during the time a piece of film is being exposed.

There is another facet to recovery by telemeter, that is, data handling. The proposed system, based on the reading grid of 60 line pairs per millimeter, produces about  $6 \times 10^7$  bits of information per frame or  $3.6 \times 10^{11}$  bits during a mission of 200 days in which 6,000 frames are exposed.

The OAO currently under development by the NASA is a standardized satellite that supplies all control communication and data handling equipment. The observational package is supplied by the experimenter to fit the OAO characteristics. The OAO would be the logical carrier on which to install the telescope and film reading equipment under discussion. The characteristics of the OAO of interest are:

Nonredundant data storage, bits . . . . .	$2 \times 10^5$
Transmission rate, bits/sec . . . . .	$5 \times 10^4$
Communication time per orbit, min . . . . .	10
Weight allowance for experiment package, kg . . . . .	455
Space available for experiment:	
Diameter, m . . . . .	1
Length, m . . . . .	2.81
Lifetime, probability of 1 year life, percent . . . . .	70

As packaged for installation in the OAO, the proposed telescope and cameras would be about 2.75 meters long and about 0.82 meter in diameter not including the film reading equipment and would have an estimated weight of over 600 kilograms. In addition, it would require about 2.35 years to transmit all the data. To increase the data storage and transmission capability of the OAO so that all data could be received in 1 year would require volume and weight increases in the storage, telemetry, and power that do not appear to be tolerable in view of the already strained weight and volume allowances of the OAO. Unless major modifications are made in the OAO and a different booster used, it does not appear that an experiment consisting of a photographic telescope with film reading equipment is compatible with the OAO. In addition, film readout systems are bulky and heavy and would add much weight and volume to the experimental package.

Either the Mercury or the Gemini spacecraft could be converted for this work. This paper is concerned with the Mercury spacecraft because early results showed this conversion was compatible with the capabilities of the Atlas Agena B booster system whereas the converted Gemini would require the use of boosters yet to be developed.

In addition to being able to perform a wide range of astronomical observational tasks, such as high-resolution photography, photometry, and spectroscopy, the recoverable orbiting astronomical observatory would permit

- (1) Recovery of the capsule, optical, and control systems for possible reuse
- (2) Study of the effects of space environment on the equipment
- (3) The recoverable OAO to serve as a test bed for the more advanced OAO of the next decade

#### PROPOSED RECOVERABLE ORBITING OBSERVATORY

Figure 1 shows a rendering of the proposed recoverable orbiting astronomical observatory in operation. It consists of a modified Mercury spacecraft, a 76-centimeter cassegrainian telescope, a camera recording system, and a precise control system.

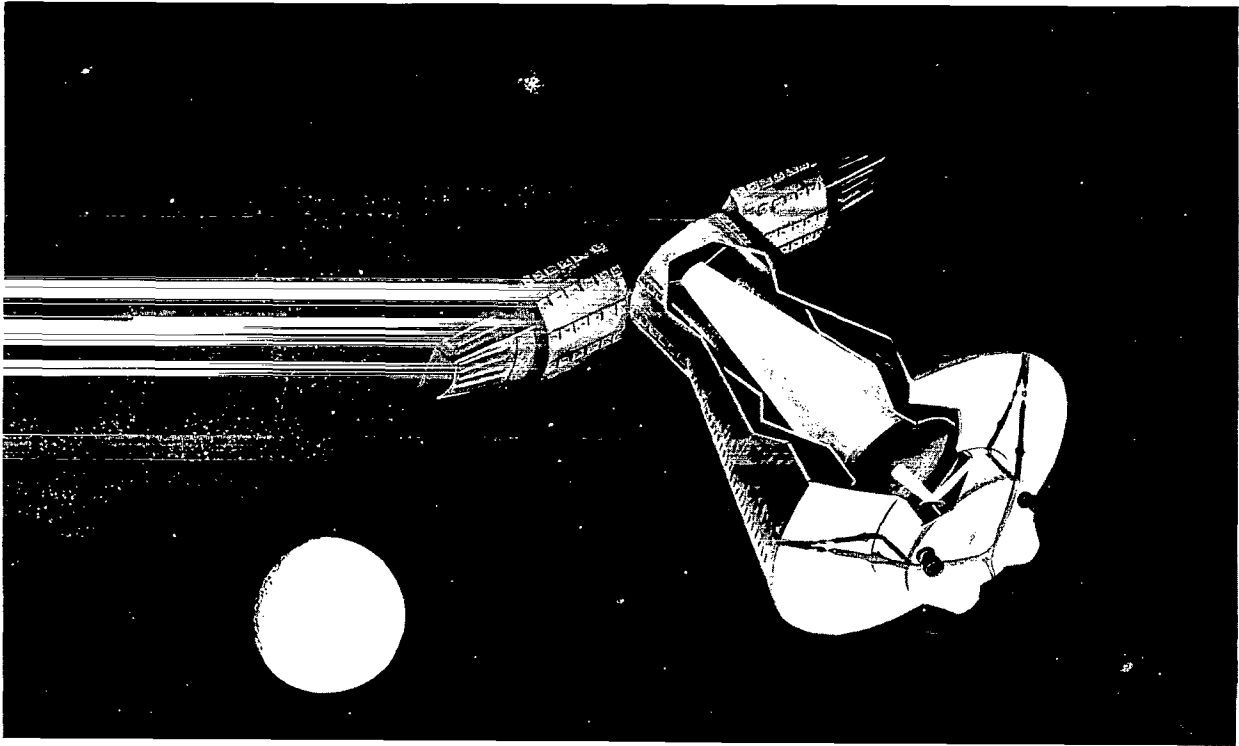


Figure 1.- Rendering of the proposed recoverable orbiting astronomical observatory in operation. L-63-6496

### The Spacecraft

The spacecraft considered for the recoverable orbiting astronomical observatory is a modified Mercury spacecraft. A cutaway drawing of this vehicle is shown in figure 2. In order to convert the Mercury spacecraft to an orbiting astronomical observatory, it is necessary to remove all equipment and the forward bulkhead of the pressure vessel, to rework the cylindrical section to obtain a clear 76-centimeter aperture, to fabricate and to install a new recovery package and operating mechanism for the clamshell doors formed by the new recovery package. In addition, new bulkheads would have to be installed to divide the interior into the telescope compartment, equipment compartment, and camera bay. The heat shield must be checked to determine whether it is adequate for reentry from a 500-kilometer orbit. The Mercury abort system would not be used. A preliminary study indicated that the major structural problems encountered would involve the new recovery package, and its operating and locking mechanisms.

As can be seen from figure 2, the telescope compartment is like an inverted T that is rotated about its stem. The optical axis of the telescope is directed along the stem of the T. The cameras and power supplies are located in the space corresponding to the base of the rotated T. The control and communications equipment are located in the equipment compartment which completely surrounds the telescope tube. The volume of the equipment compartment is about 1 cubic meter less the space required to store the movable secondary mirror.

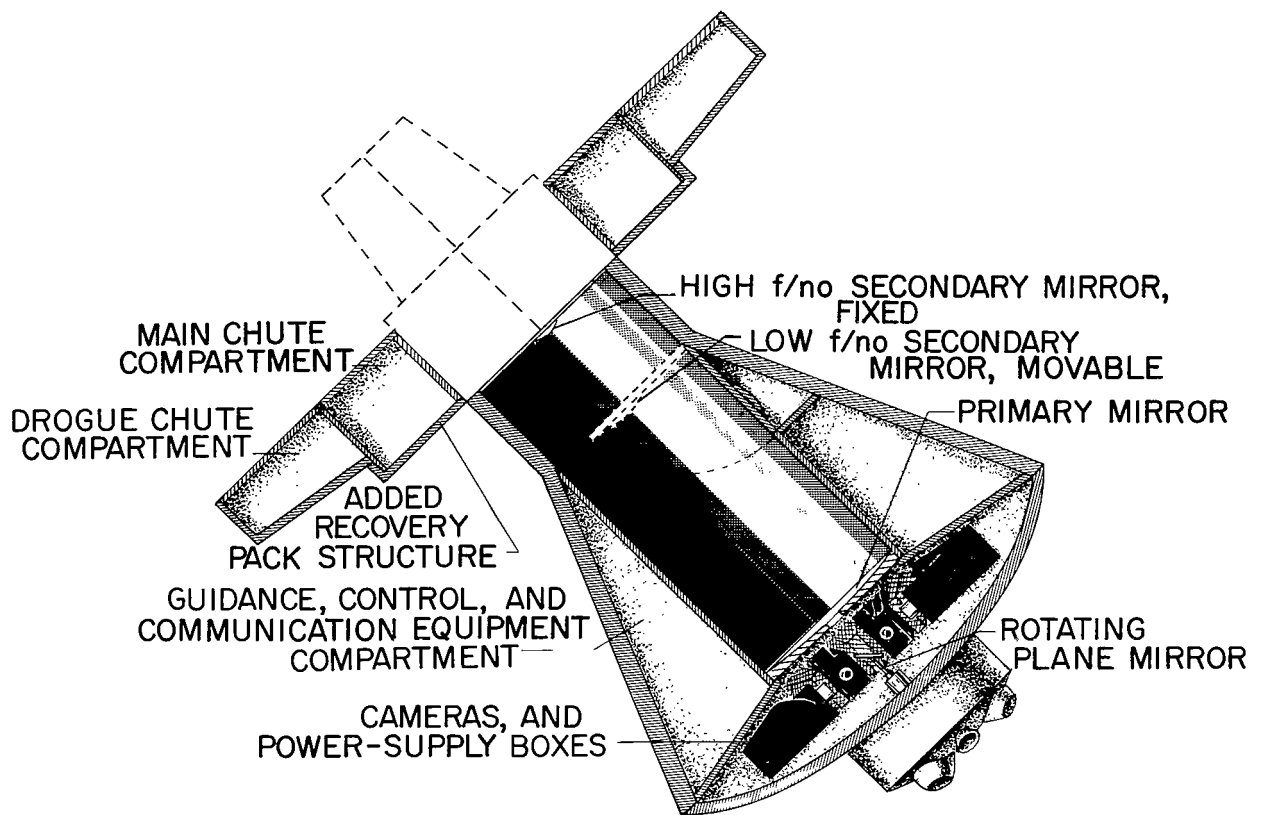


Figure 2.- Cross section of recoverable orbiting astronomical observatory.

A preliminary weight estimate based on proposed weights of OAO systems, experiments, and a preliminary layout of the proposed photographic telescope and cameras indicated the following weight breakdown:

	Weight, kg
Telescope and cameras . . . . .	610
Control communications and power . . .	640
Structure, reentry, and recovery . . .	900
Total . . . . .	2150

Weight estimates pertaining to the structure, reentry, and recovery equipment were made by engineers familiar with the Mercury spacecraft.

This launch weight is above the capability of an Atlas booster for a 500-kilometer orbit. An Atlas Agena B can place 2,275 kilograms into a 500-kilometer orbit. The use of the Atlas Agena B as the booster allows an increase in weight of 125 kilograms before the limit of the booster is reached.



## The Telescope

Figure 2 shows the telescope installed in the spacecraft. The telescope is a cassegrainian type with a 76-centimeter aperture and was selected because it was best suited to the space limitations of the Mercury spacecraft. In addition, the image plane was easily accessible for image recording. As conceived, the telescope would have two alternate secondary mirrors, a high  $f/no$  secondary which is fixed, and would be used for high-resolution photography of discrete objects and a low  $f/no$  secondary which would be used for studies requiring low resolution such as background radiation studies. The light paths for the two secondary mirrors are shown in figure 3. The cassegrainian-type telescope has astigmatism, coma, and curved field problems. When the high  $f/no$  secondary mirror is used, it is desirable to make these aberrations as small as possible. The noted aberrations can be controlled to a large degree by grinding the primary and high  $f/no$  secondary as aspherical surfaces, the former undercorrected and the latter overcorrected. This condition means that the low  $f/no$  secondary-primary combination may not be as well corrected. However, this correction is not as important because for the type of photographic work for which the low  $f/no$  secondary mirror would be used, high correction is less important. Field curvature can be corrected by the use of a curved film plane or by corrections in the optical relay system, the lens system that occurs between the image tube and recording film. (See fig. 4.)

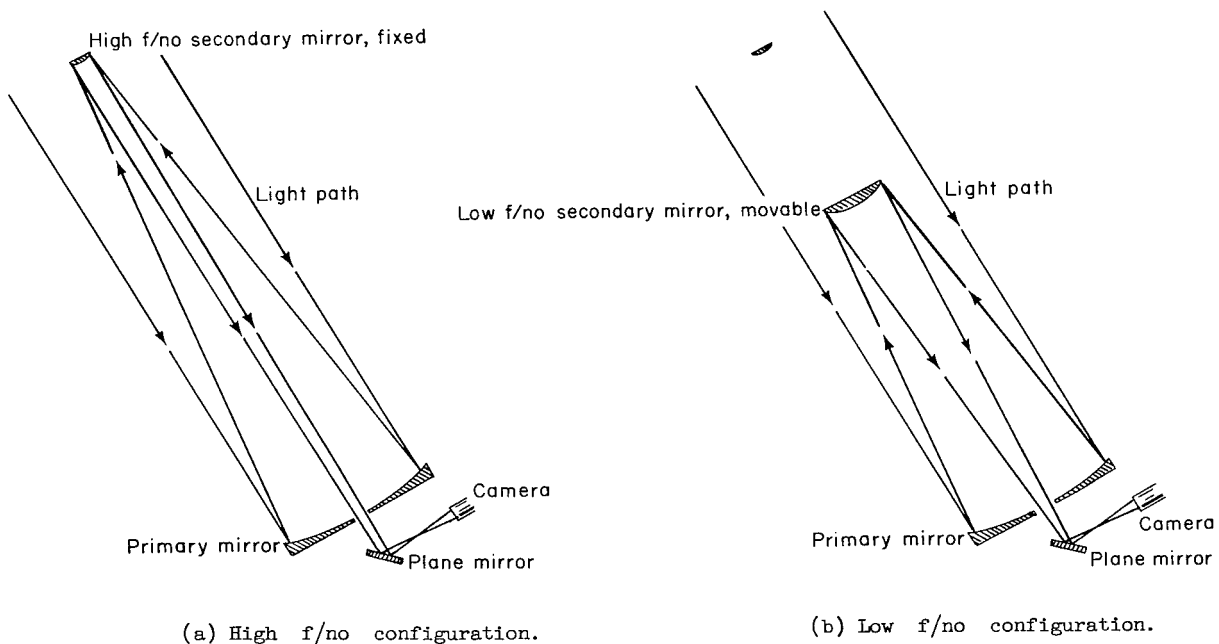


Figure 3.- Telescope light paths.

The following table gives some of the characteristics of the proposed telescope:

	High f/no secondary mirror	Low f/no secondary mirror
Aperture . . . . .	76 cm	76 cm
f/no (effective) . . . .	32.5	5.1
Plate scale . . . . .	8.32 sec/mm	53.4 sec/mm
Resolution . . . . .	0.152 sec	0.152 sec
Field of view . . . . .	9.72 min	1.066 deg
Limiting magnitude . . .	$\approx 22^*$	$\approx 22^*$

\*In blue light at prime focus saturated film. (See fig. 2, ch. 1 of ref. 4.) Sky magnitude decreased to 24.2 to account for lack of atmosphere.

The third mirror shown in figures 2 and 3 is an optically flat front surfaced mirror. This mirror turns the light at a right angle to the optical axis and rotates about the optical axis to direct the light into the cameras.

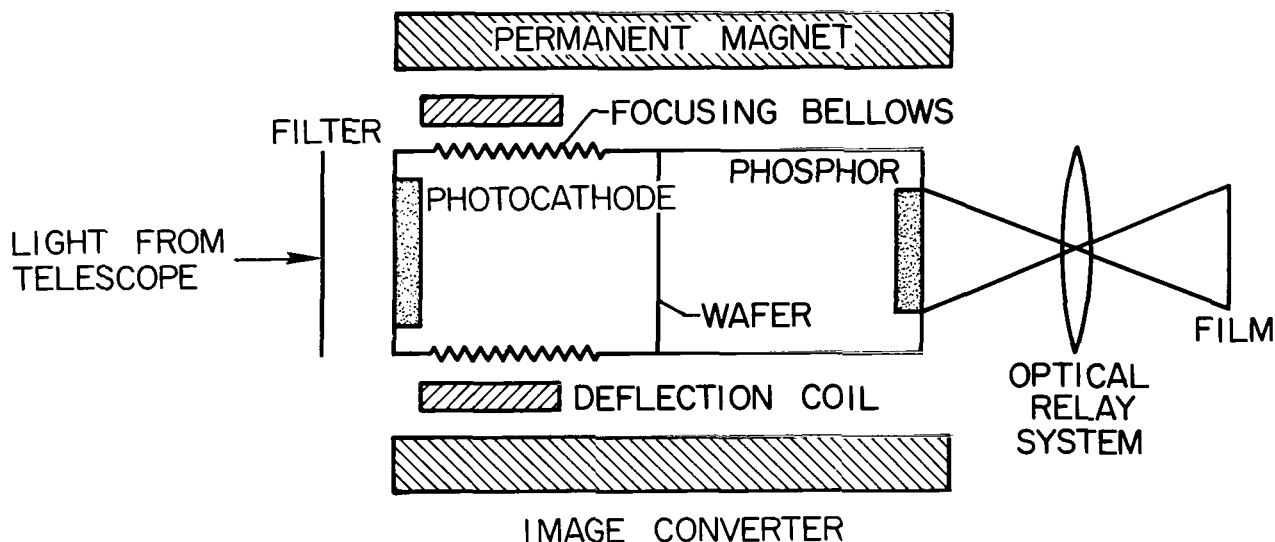


Figure 4.- Schematic of the proposed recording cameras.

The telescope should approach as closely as possible a diffraction-limited optical system. As it is desired to record light with wavelengths of less than 3,000 Å, the mirror surfaces should be aluminum overcoated with magnesium fluoride. The mirror material would probably be either fused quartz or beryllium because of their overall favorable characteristics such as thermal stability, light weight and, in the case of quartz mirror, mirror figure stability.

#### The Recording Cameras

Each recording camera (see fig. 4) consists of a filter, an image converter tube, optical relay system, and a film holder. In addition, not shown are the film storage drums for exposed and unexposed film and the containers for the developing web. The general details on the camera are as follows:

Type: Image converter-intensifier type tube, magnetically focused (permanent magnet) 10-centimeter photocathode and output phosphor. (It is understood that production of astronomical quality image tubes of this type is about to be started.)

Film: Type: thin base  
Size: 70 millimeter  
Frame size: 70 millimeter by 70 millimeter

Optical relay system: Wide-angle, short-focal-length, high-resolution, high-speed system. The relay ratio should be 1:1.

Resolution: Limited by the optical relay system

Film capacity: 75 meters per camera, approximately 1,000 frames

Development of film: Webb process

Shielding: It is necessary to shield unexposed film, exposure chamber, and film development tracks. The shielding would be aluminum and lead with a density of 15 grams per square centimeter.

Table I presents information for a coordinated set of six cameras to cover the spectrum between 1,200 Å and 11,000 Å.

TABLE I.- CAMERA AND FILTER DATA

Camera	Color	Filter	Photocathode	Approximate band pass
1	U <sub>1</sub>	Calcium fluoride <sup>1</sup>	Rb-Te	1,220 to 3,200
2	U	Corning 9863 <sup>2</sup>	S-20	3,000 to 3,800
3	B	Corning 5030 2 mm Schott GG-13 <sup>2</sup>	S-21	3,800 to 5,000
4	V	Corning 3384 <sup>3</sup>	S-10	5,000 to 6,800
5	R	Schott RG-2 <sup>3,4</sup>	S-20 or S-3	6,400 to 8,500
6	IR	1 mm Schott VG-6	S-1	8,500 to 11,000

<sup>1</sup>Calcium fluoride was selected in preference to lithium fluoride because the short wavelength cutoff is temperature dependent. Short wavelength cutoff of U<sub>1</sub> camera is adjusted to exclude Lyman α radiation shifted less than 4 Å. The filter would have to be heated to about 300° K. (See refs. 6 and 7.)

<sup>2</sup>Filter defined in reference 8.

<sup>3</sup>Filter defined in reference 9.

<sup>4</sup>Most extragalactic observations from the earth will undoubtedly be made in the red color band within the spectral region defined by the S-20 photocathode and Schott RG-2 filter. (See ref. 9.) This camera has been included to provide a standard for the calibration of earthbound observations.

The image tube for the U<sub>1</sub> camera is a laboratory item. Therefore, research and development would be necessary on the photocathodes and image tubes in order to obtain a flight-rated camera.

Several camera systems were considered and image tubes were selected because

(1) They permit a small aperture telescope to record fainter objects. (A 30-inch telescope with image tubes is theoretically the equivalent of a 300-inch telescope recording on film.) (See chapter 1 of ref. 4.)

(2) They permit shorter exposure times and thus reduce the time during which extremely small drift rates must be maintained.

(3) They are required to record the extreme ends of the electromagnetic spectrum.

(4) All light is converted to the same wavelength and therefore only one type of film and one type of developing web are required.

The heart of these cameras is the image tube. This device uses a photocathode to convert the incoming photons to photoelectrons. The photoelectrons impinge on the wafer (possibly a dynode) which amplifies the signal and the amplified photoelectrons finally impinge on a phosphor which converts them to visible light. The use of the image tube permits photography to be extended to the far ultraviolet region and because the image tube acts as a light amplifier permits a reduction in exposure time or the extension of photography to fainter magnitudes than could be recorded with a given telescope when not equipped with image tubes.

Several types of image tubes are available. (See refs. 4, 5, and 10.) The image tubes selected are magnetically focused and recorded on photographic film sensitive to blue light if a P-11 phosphor is used for the output of the image tube. These tubes are standard except for the size, an effective diameter of 10 centimeters is required, and the deflection coils that are shown in figure 4. Larger tubes have been built (see refs. 4 and 11), but it appears some development will be required to obtain the desired quality of the photocathode. The magnetically focused tube recording on photographic film was selected in preference to the electrostatically focused tube recording directly on nuclear emulsions because it was felt that the magnetically focused tube could better withstand the rigors of launch and that the photographic film would be easier to protect against radiation than the nuclear emulsions.

As indicated by McGee (see ref. 5, pp. 81-103), it is possible to focus the magnetically focused image tube so that the resolution is between 80 and 100 line pairs per millimeter at each stage. The output phosphor has high resolution but it is not the factor that limits the resolution of the image tube camera. The limiting resolution in the image tube camera usually occurs in the optical relay system that transfers the image from the phosphor to the film.

When the film is recovered, the film reader is eliminated and higher resolution film can be used to improve the information content of the photographs. When the resolutions of the phosphor and optical system are taken into account, it appears that the use of a higher resolution film would increase the information by a factor of about 1.8 which would mean a total information gain over film reading systems of about 4.

As previously indicated, the use of the image tube permits a reduction in exposure time. Based on the information presented in reference 4, it is not unreasonable for an exposure requiring 15 minutes without image tubes to be made in approximately 20 seconds with an image tube. This reduction in exposure time will have a good effect on stabilization problems as it reduces the time extremely precise pointing has to be maintained.

The unexposed film must be protected from radiation damage. The determination of good protection requires an analysis (beyond the scope of preliminary study) that takes into account dose rate, shielding, emulsion, spacecraft structure and material, and mission duration. Some rough calculations indicate that if a slow speed film is used, shielding of about 15 grams per square centimeter should be adequate for the mission duration previously stated.

The calibration of the cameras would be accomplished by a standard light source reflected from the secondary mirror or by photographing a standard star. The focusing of the cameras could be accomplished by focusing on a star and maximizing the high-frequency content of the scene.

### The Control System

The control system for the recoverable orbiting astronomical observatory requires a high degree of precision, and drift must be held to less than 0.08 second of arc during exposures which can vary from a few seconds to more than an hour. The long exposure times represent very distant objects and here less precision can be tolerated as the object will be unresolved. In exposures of 1 hour or less, drift should be controlled to 0.08 second of arc or better.

One of the few control systems being developed that has such pointing accuracy is the OAO control system. This system can hold attitude within 15 seconds of arc for 50 minutes which is a drift rate of 0.005 second per second or about 150 times too high for the present requirements. The OAO has a fine control system that can control the point to 0.1 second of arc. The error signal for this control mode is generated by the prime experiment. McGee (ref. 5, pp. 81-103) suggested that the image tube could be used as a fine control system. To accomplish this use, the image tube is equipped with deflection coils. (These coils are similar to the orbiting coils used on the first stage of image orthicon tubes. The terminology used in ref. 5 has been used in this paper.) The image is allowed to drift on the face of the photocathode and the deflection coils stabilized it so that the image is steady on the output phosphor and the image motion on the phosphor cannot exceed 0.01 millimeter. The electron beams in video tubes are routinely controlled to 0.025 millimeter and laboratory models have beam control to 0.0025 millimeter so it would seem that there are no great technical barriers to the use of this system of control. One of the more important aspects of the beam control system of image stabilization is the fact that no moving parts are involved and inertia is not a factor in its response. Most important, the type of fine control system considered would introduce no disturbing torques on the recoverable OAO. The use of image tubes also helps the stabilization problem because of the reduction in exposure time that is obtained. This reduction in exposure time means that extremely fine pointing is required for short time periods compared with regular photography. The deflection coil

system of stabilization takes care of the declination and right ascension axes and leaves rotations about the optical axis of the telescope to be controlled. The basic OAO control system provides for the control of roll to about 1 second per second. Over a long period this rate is too high to be tolerated. To be in line with the drift about other axes, the smear rate would have to be reduced by a factor of 20. The control of this rotation about the optical axis could be accomplished by an optical device like a mirror Dove or Pechan prism which would be controlled to derotate the image.

Because of the precession required in the fine control (0.08 inch of arc), the error signal for this system would have to be obtained from the main telescope optics. Several methods of obtaining this signal have been developed for OAO and balloon projects in astronomy. Because of work already done, the development of this error signal is not considered a major problem. The details of the exact system would have to be worked out during the detail design of the observing and control systems.

In summary, the orbiting astronomical observatory control system not associated with an experiment is not sufficiently precise for high-resolution photography and a fine new control system would have to be provided. The use of deflection coils on the image converter tubes and a precisely controlled mirror Dove or Pechan prism appear to offer possibilities of achieving the required fine control but the detection of the very small displacement rates involved present a problem.

The high thrust control jets used for the original spacecraft have to be retained to provide control during reentry. The OAO control system would have to be modified to provide a reentry control mode for the spacecraft or the Mercury reentry control system would have to be retained to provide control for this phase of the flight.

### Operation

The converted Mercury spacecraft would be launched into a nominally circular orbit inclined approximately  $32^\circ$  to the equator. This inclination is about the same as the Mercury orbit and that of the OAO; thus, the same ground tracking and communication facilities could be used. The orbital altitude is 500 kilometers and places the spacecraft well above the airglow. (See refs. 12 and 13.) The period of this orbit is about  $5.7 \times 10^3$  seconds. The estimated life of the satellite in this orbit is 1 year.

The sequence for the use of control systems during a mission would be as follows:

- (1) The Atlas-Agena guidance system would provide control during the launch and orbit injection phases of the mission.

- (2) The modified OAO control system would provide control during the period when the observations were being made. At the end of this period the heat shield would be pointed in the direction of motion.

(3) The Mercury reentry guidance system or its equivalent would take over after the proper orientation had been achieved and control the vehicle until the parachutes were deployed.

The average exposure used to estimate mission duration was 900 seconds (see ref. 2), and it was assumed that the exposure of four frames per orbit would be reasonable. This assumption indicates a mission duration of about 100 days for the photography; however, the actual mission would probably have a duration of 100 to 200 days. The spacecraft would be returned to earth on the first orbit after the final exposure and it should be landed in the Bermuda recovery area. The standard Mercury letdown procedure with parachutes could be used.

Figures 2 and 5 indicate the use of batteries as a power supply. For a mission of 200 days, the use of batteries as the sole power source would be impractical because of the weight of the batteries. Solar panels or some other means of recharging the batteries would have to be provided so that the weight of the power supply system could be kept within reasonable limits.

The mode of operation of the observatory was selected to promote identification of the area under observation. The first set of six photographs would be taken with the low f/no secondary mirror and would be centered on the object to be observed by high-resolution photography. Enough area  $1^{\circ}$  by  $1^{\circ}$  is covered by these photographs to identify the area under observation from known stars. These films would also give background data. A second set of six high-resolution film exposures would then be taken of the desired object about which the first photograph was centered.

#### Problem Areas

In a preliminary study, it is impossible to investigate all the problems adequately and to define specifically all the problem areas. The most important areas where problems existed or where it was apparent that more experimental and/or development work was needed are:

- (1) The integration of
  - (a) The OAO control system
  - (b) The OAO communications system
  - (c) The development of the fine-image stabilization system
- (2) Stability of the optical system
- (3) The development of wide-angle optical relay system
- (4) The effect of stray magnetic fields on the image tubes
- (5) The modifications to the spacecraft structure and the heat shield
- (6) Thermal control of the precession optical system.

## A Possible Observational Mission

The recoverable orbiting astronomical observatory is capable of performing a great many observational missions of interest to astronomy. The broad spectrum of space observations for astronomy is covered in reference 7. In order to show what could be expected from the recoverable orbiting astronomical observatory a mission for the observation of galaxies is considered. For this discussion it was assumed that the cameras given in table I would be used. The camera bay arrangement shown in figure 5 was assumed.

The use of the cameras and filters given in table I would give a spectral coverage from  $1,220 \text{ \AA}$  to about  $11,000 \text{ \AA}$ . Three of the cameras record the standard U, B, V regions (ref. 8); the fourth camera records in the red region (ref. 9). This red region is important because (1) the red photovisual index can be determined and (2) it is the wavelength region in which terrestrial observations will be made. The data from the fourth camera can be used as check points for terrestrial observations. The fifth camera records the infrared region out to  $11,000 \text{ \AA}$ . The sixth records the ultraviolet region from  $1,220 \text{ \AA}$  to the short wavelength cutoff of the U camera. The far ultraviolet camera, camera  $U_1$ , is equipped with a heated calcium fluoride filter so that all ultraviolet radiation which shifted less than  $4 \text{ \AA}$  to the red (corresponding to a

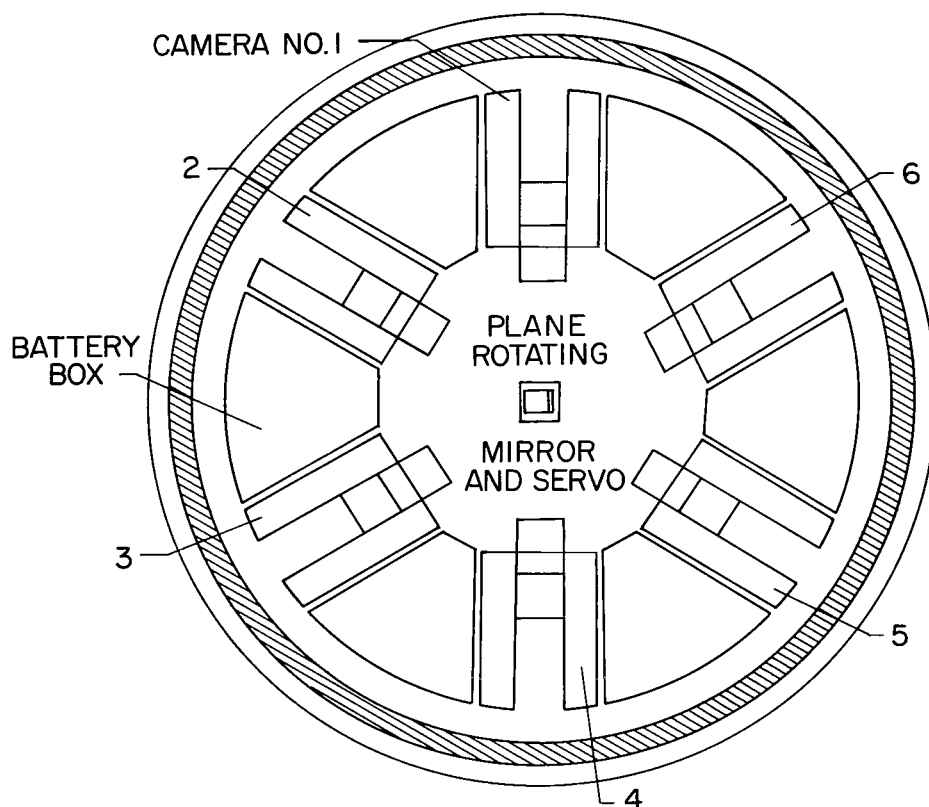


Figure 5.- Proposed camera bay arrangement.



velocity of recession of 1,000 kilometers per second) is excluded by the filter. (See refs. 6 and 7.) This exclusion eliminates the problem of radiation from the geo-corona and galactic ultraviolet saturating the field and obscuring the extragalactic Lyman  $\alpha$  radiation which is of prime interest.

The data that this photographic mission could obtain may be summarized as follows:

(a) From each type (color) of plate, the following data are obtained: magnitude for color of plate, angular diameter, and isophotos.

(b) When a set of six plates for a given galaxy are taken together, the following data on a galaxy would be obtained: apparent bolometric magnitude; color index, B - V; color excess, U - B; red color index, V - R; distribution of various colors in galaxy; based on the distribution of various colors in galaxy, the distribution of population I and population II stars; the red shift by rectification of the light curve (ref. 14); distribution of luminosity through a galaxy over a wide spectral band; red magnitude camera data that could be used to establish a zero point for the calibration of surfacebound observations and because the data are recorded on film, unusual features such as the gas jet in M-87 and supernovas in distant galaxies could be detected.

(c) Film taken with the low f/no secondary mirror would provide data on the intergalactic background radiation.

As the observations would cover galaxies with small and large red shift, the problem of the aging of galaxies, the variation of luminosity with time due to stellar evolution, could be studied by comparing the ultraviolet and visual plates of nearby galaxies with the visual and infrared plates of distant galaxies when the galaxies are of the same type. Lastly, the sharp image on the plates would provide sufficient information to identify the type of galaxy observed. (See ref. 2 for a discussion of the classification system of galaxies.) In addition, the low background of the recording system would permit better reading of the halo of the galaxy against the background and therefore better magnitude and angular diameter data.

These anticipated results would contribute information that would have a direct bearing on cosmological research, galactic evolution, the structure of galaxies, and the distribution of gas and background radiation in the Universe.

#### CONCLUDING REMARKS

A preliminary study of a possible conversion of the Mercury spacecraft to a recoverable orbiting astronomical observatory for high-resolution photography and study of intergalactic background has been made. The results indicate that an information gain up to a factor of 10 over telemetered systems can be achieved if the fine stabilization system can hold drift to less than 0.08 second of arc during exposure.

Because the observatory would be recoverable, the original data could be obtained and the precise control and optical systems saved for further use. In addition, the recovery of the system permits an evaluation of the effect on the space environment and instrumentation and would make possible the use of the Mercury telescope as a test bed for equipment and techniques that would be applicable to the larger and more sophisticated orbiting astronomical observatories of the future.

The anticipated observational results would contribute to several branches of astronomy including the stellar, nebular, and galactic divisions of astronomy. When used for the observation of galaxies, the results would contribute to the elucidation of the problem of the structure and evolution of the Universe and to a better understanding of galactic evolution and galaxies in general. In addition, the suggested operation would permit (1) the positive and permanent recording of the observing direction, (2) identification of the type of source, and (3) a means for a statistical study of atmospheric extinction and the calibration of earthbound observations. The configuration of the proposed recoverable orbiting astronomical observatory would be applicable to observations concerned with multicolor photometry of stars and nebulae without major changes.

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National Aeronautics and Space Administration,  
Langley Station, Hampton, Va., May 22, 1964.

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